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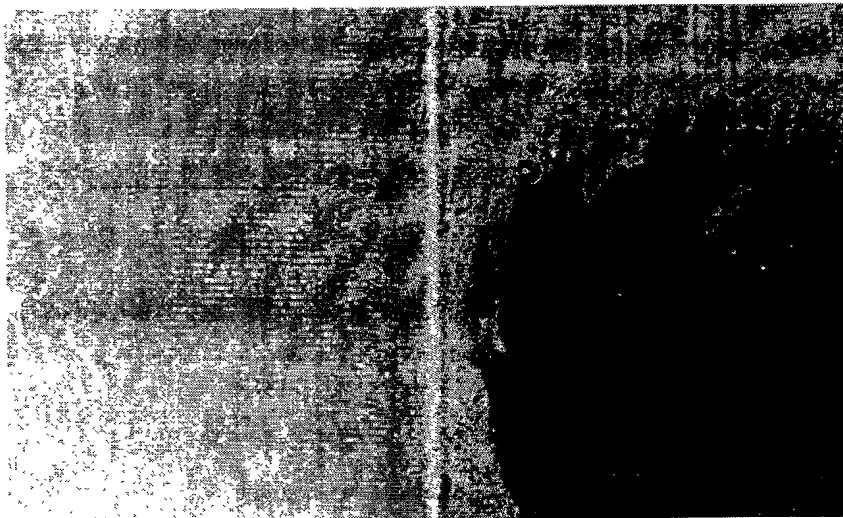
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(54) Title: METHOD FOR IMPROVING THE SURFACE QUALITY OF HYDROGEL ARTICLES



(57) Abstract: The invention provides a method of improving the surface quality of hydrogel articles comprising the step of: pro-  
cessing the article in a workable state in the presence of a non-volatile hydrophilic plasticizer.



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**“METHOD FOR IMPROVING THE SURFACE QUALITY  
OF HYDROGEL ARTICLES”**

**FIELD OF THE INVENTION**

This invention relates broadly to a method of improving the surface quality of hydrogel articles. In a particular form, the invention relates to a method of treating hydrogel articles prior to lathing, which treatment improves the surface quality of the lathed article. In a particularly preferred form the invention relates to articles produced according to the method.

**BACKGROUND ART**

- 10 Polymeric hydrogels are extensively used for manufacturing soft, hydrophilic ocular devices such as contact lenses, intraocular lenses or artificial corneas. In all these applications, the anterior and posterior surfaces must be smooth and optically clear to the best possible level. Broadly, these devices may be made by two procedures.
- 15 According to one procedure, the polymerisation of appropriate monomers is performed in casting moulds in the absence of solvents or diluents providing rigid articles generally termed “xerogels”. Upon hydration, the xerogels become hydrogels, the latter being in the soft, pliable state in which the ocular devices are generally used. Prior to hydration, the xerogels may be subjected to mechanical
- 20 processing, which in the context of the specification is understood to mean processes performed on polymeric articles designed to modify or improve its shape, profile or surface such as lathing, cutting, grinding or polishing.

Alternatively, the articles are cast in moulds in the presence of solvents or diluents, (commonly water or/and water soluble organic solvents), preserving the hydrogel state during all stages of the manufacture. In this case, additional machining of the surfaces of the resulting articles (i.e. hydrogel blanks) is generally required, because of possible surface irregularities and in order to achieve the desired dimensional and optical parameters. Mechanical processing can only be conducted on articles that are in a rigid state. Hydrogels that are soft and pliable at room temperature must be cooled to such a state before

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mechanical processing. Hydrogels must be cooled to temperatures less than the freezing point of the solvents comprising said hydrogels to become rigid. Hydrogels lathed under these conditions however typically comprise surfaces with irregular crevices of microscopic dimensions.

- 5 The need to control the stress occurring in hydrogels and also to modulate their mechanical properties and behaviour during machining is recognized in the art. For example, U.S. Pat. No. 3,699,089 issued to Wichterle discloses the inclusion of water-soluble organic solvents in monomer mixtures that do not contain water. The resulting xerogels had reduced brittleness and higher strength due to the  
10 plasticising effect of the added solvents. The aforementioned patent does not disclose freezing of hydrogels or their machining in such state.

- Additionally, both U.S. Pat. No. 4,322,139 and its division, U.S. Pat. No. 4,512,461, both issued to Wichterle, disclose the use of water-soluble agents including glycerol, glycols, or polyglycols as components of the swelling agents for  
15 treating hydrogel contact lenses. After swelling, the said contact lenses were planarized, dried, grinded or polished in order to remove defects and re-hydrated to the initial convex shape. It is disclosed in the aforementioned patents that the presence of the water-soluble agents reduces the brittleness of the dried planarized contact lenses, such assuring better mechanical processability by  
20 grinding, polishing or cutting. The aforementioned patents do not disclose mechanical processing of frozen hydrogels. According to the teaching of these patents, the improvement of mechanical properties of the contact lenses as xerogels was based entirely upon the plasticising effect of the agents added to the swelling agent.

- 25 Further, U.S. Pat. No. 4,093,361 issued to Erickson and Neogi relates to a method for eliminating the distortions and stresses occurring upon hydration of composite hydrogel articles such as contact lenses with a hard core and a soft skirt. To achieve this, certain water-soluble agents were incorporated into the hydrogels prior to polymerisation and hydration. According to the aforementioned  
30 patent, the agents include polyethylene glycol and derivatives, aromatic acids, soaps and surfactants, and water-soluble synthetic polymers. The patent does not

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disclose mechanical processing of frozen hydrogels, and does not relate to the cryoprotective properties of the agents.

Additionally, U.S. Pat. No. 4,956,432 issued to Vacik, Obereigner and Souckova discloses the preparation of hydrogels by copolymerisation of N-substituted pyrrolidone derivatives with acrylic monomers. It is disclosed in this reference that the addition of polar solvents such as glycerol or glycols in the monomer mixture can result in materials devoid of stress, after swelling/washing in water and drying to xerogels. According to the aforementioned patent, the presence of the said agents at the time of polymerisation induced a more ordered structure of the crosslinked polymers network, such reducing the stress. The said agents are removed from materials by washing prior to drying and machining. The patent neither discloses the effects of the said agents on frozen hydrogels, nor their machining in such state.

Further still, Jap. Pat. 56-94240 issued to Suzuki discloses embedding agents for slicing large sections of organ tissue for histopathological examination (microscopy, autoradiography). According to the aforementioned patent, the common embedding agent for large organ sections was carboxymethyl cellulose, which presented several shortcomings such as formation and build-up of crystals upon freezing, fragility, and disintegration to a powder upon slicing with the tools of the art. The patent discloses compositions based on poly(vinyl alcohol) of a particular degree of polymerisation, capable of eliminating these shortcomings during slicing at temperatures between  $-15^{\circ}\text{C}$  and  $-20^{\circ}\text{C}$ . The compositions disclosed are solutions in water of PVA, sodium alginate, glycerol and sucrose. According to the inventor, sodium alginate reduces friction during the cutting, while glycerol and sucrose prevent the build-up of crystals upon freezing. Although the aforementioned patent does exploit the cryoprotective properties of certain agents (glycerol, sucrose) with the purpose of improving mechanical processability, the invention relates to aqueous solutions, not to hydrogels, which are insoluble in water. Further, the invention does not relate to machining the polymers as such, but to the slicing of biological matter where the solution of a polymer serves only as an embedding medium (support) during freezing and subsequent cutting.

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This invention seeks to provide a method of ameliorating these problems of the cryogenic lathing process and more specifically to provide an article with a high quality smooth finish.

#### SUMMARY OF THE INVENTION

5 The applicant has discovered that in the conditions of the present invention hydrogel articles treated with a non-volatile hydrophilic plasticizer are much less brittle, cutting has a uniform course and the resulting surfaces are much smoother than in the case of hydrogel articles that were not treated with non-volatile hydrophilic plasticizer prior to lathing. This effect is believed to be a combined  
10 result of the reduction of stress to the polymer mass associated with its preparation in a workable state, of a smaller size of ice crystals and of the presence of non-volatile hydrophilic plasticizer in a fluid state within the intercrystalline voids.

The presence of the non-volatile hydrophilic plasticizer strongly hinders or even  
15 arrests nucleation and growth of ice crystals as well as depressing the temperature at which freezing of water occurs. As a result, the ice crystals form in reduced amounts, they are smaller and have shapes different from the shape of the ice crystals formed by normal freezing. Further, the formation, propagation, distribution and dissolution of the ice crystals formed in the presence of non-  
20 volatile hydrophilic plasticizer are much slower than in their absence.

According to the invention there is provided a method of improving the surface quality of hydrogel articles. In a particular form, the invention relates to a method of treating hydrogel articles prior to lathe machining in a workable state, which treatment improves the surface quality of the lathed product.

25 The invention also relates to products produced according to the method.

Other aspects and advantages of the invention will become apparent to those skilled in the art from a review of the ensuing description, which proceeds with reference to the following illustrative drawings.

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BRIEF DESCRIPTION OF THE DRAWINGS

**Figure 1** is a frontal photograph of the lathed surface of a polyHEMA hydrogel blank that was not subjected to treatment in glycerol; and

**Figure 2** is a frontal photograph of the lathed surface of a polyHEMA hydrogel blank that was treated in a solution of 15% by weight glycerol in water.

DETAILED DESCRIPTION OF THE INVENTION**General**

Those skilled in the art will appreciate that the invention described herein is susceptible to variations and modifications other than those specifically described.

10 It is to be understood that the invention includes all such variations and modifications. The invention also includes all of the steps, features, compositions and compounds referred to or indicated in the specification, individually or collectively, and any and all combinations or any two or more of the steps or features.

15 The present invention is not to be limited in scope by the specific embodiments described herein, which are intended for the purpose of exemplification only. Functionally equivalent products, compositions and methods are clearly within the scope of the invention as described herein.

20 Throughout this specification, unless the context requires otherwise, the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

Other definitions for selected terms used herein may be found within the disclosure of the invention and apply throughout. Unless otherwise defined, all other scientific  
25 and technical terms used herein have the same meaning as commonly understood to one of ordinary skill in the art to which the invention belongs.

**Disclosure of the preferred embodiments**

In accordance with the present invention, there is provided a method of improving the surface quality of hydrogel articles comprising the step of: processing the article in a workable state in the presence of a non-volatile hydrophilic plasticizer.

- 5 As used herein "processing" of the hydrogel refers to any process that is capable of shaping, cutting, grinding or polishing of a hydrogel. Usually such processing will be carried out by mechanical means that are capable of modifying or improving a hydrogel's shape, profile or surface. An alternate form of processing might be through the use of high-pressure fluid jets. Preferably, the processing
- 10 that is referred to will include the mechanical lathing of the hydrogel followed by processes which grind and or polish the hydrogel.

- As used herein "workable state" refers to the state of the hydrogel at the time of processing. While hydrogels may be processed in many forms, the present invention is preferably employed for the processing of hydrogels in a rigid or semi-
- 15 rigid form as might arise from the process of freezing. Generally the hydrogels will display sufficient rigidity to permit lathing and or grinding and or polishing.

- The advantages associated with the present invention include for example: (a) providing a means for reducing or eliminating stress and distortion of hydrogel articles upon exposure to reduced temperatures; and (b) providing a means for
- 20 improving the quality of the surface of hydrogel articles lathed in a rigid state.

In a preferred embodiment the invention provides a method of improving the surface quality of hydrogel articles comprising the step of: mechanically processing the article in a rigid or semi-rigid state in the presence of a non-volatile hydrophilic plasticizer.

- 25 The hydrogel articles that may be processed according to the present invention are not limited in any context other than they must be capable of being placed in a workable state for processing. Preferably the hydrogel articles will be ocular lenticular devices such as contact lenses, intraocular lenses and artificial corneas or the like.



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Representative of the hydrogels useful in conjunction with the cryoprotective agents and method of the present invention are:

- a. Hydrogels derived from 2-hydroxyethyl methacrylate (henceforth designated as HEMA), crosslinked with any of the agents known in the art.
- 5 b. Hydrogels derived from other hydroxylated methacrylates and acrylates, such as 2-hydroxyethyl acrylate, 2-hydroxypropyl methacrylate and acrylate, glycerol methacrylates and acrylates, and many other well known in the art, as such or as mixtures thereof, crosslinked with any of the agents known in the art.
- 10 c. Copolymers of HEMA with hydrophobic aliphatic methacrylates or acrylates, such as methyl methacrylate, or other members of the homologue series, crosslinked with any of the agents known in the art.
- d. Copolymers of HEMA with 2-alkoxyalkyl methacrylates or acrylates, such as 2-ethoxyethyl methacrylate, crosslinked with any of the agents known in the art.
- 15 e. Polymers and copolymers derived from acrylamide and its derivatives, and various combinations with hydroxylated methacrylates and acrylates, or with N-vinylpyrrolidone and derivatives, crosslinked with any of the agents known in the art.
- 20 f. Polymers and copolymers derived from N-vinylpyrrolidone and its derivatives, and various combinations with hydroxylated methacrylates and acrylates, or with acrylamide and derivatives, crosslinked with any of the agents known in the art.
- g. Copolymers of HEMA, or of any of the aforementioned monomers, with 25 methacrylates or acrylates of poly(ethylene glycols), crosslinked with any of the agents known in the art.
- h. Silicone acrylate hydrogels, cross linked with any of the agents known in the art.

The list is not limiting since any water-absorbable polymer may function as a  
30 substrate in the method of the present invention. Except in conjunction with their use as examples of manufactured articles in the present invention, the aforementioned ocular devices *per se* do not constitute a part of this invention.

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Preferably, the non-volatile hydrophilic plasticizer is a water-soluble cryoprotective agent known in the art. Water-soluble cryoprotective agents suitable for use according to the present invention include, for example: glycerol, glycols, poly(ethylene glycols), polyols, water-soluble synthetic polymers (e.g. polyvinylpyrrolidone), gelatin, albumin, natural gums, monosaccharides and polysaccharides.

While the present invention is described in the context of using a single non-volatile hydrophilic plasticizer, those skilled in the art will appreciate that combinations of non-volatile hydrophilic plasticizers may be employed in the method of the invention. Where combinations of plasticizers are used in the invention they will preferably be miscible when in the presence of each other.

It is contemplated according to the present invention that the hydrogel article is contacted with enough non-volatile hydrophilic plasticizer to ameliorate the stress and distortion of hydrogel articles upon cooling and/or to improve the quality of the surface of hydrogel articles upon lathing of the article. Those skilled in the art will appreciate that the relative amount of non-volatile hydrophilic plasticizer that is contacted with the hydrogel article will depend on the type of the non-volatile hydrophilic plasticizer employed. The non-volatile hydrophilic plasticizer may be used as a neat liquid or may be diluted. Where the non-volatile hydrophilic plasticizer is diluted, the resultant solution preferably ameliorates the stress and distortion of hydrogel articles upon cooling and/or improves the quality of the surface of hydrogel articles upon lathing of the article.

The non-volatile hydrophilic plasticizer may be diluted in any fluid with which the non-volatile hydrophilic plasticizer is miscible. Preferably, where the hydrogel article is to be used for therapeutic purposes in connection with a patient, the fluid will be physiologically acceptable. Physiologically acceptable solutions might include for example purified (e.g. distilled and deionised) water.

Preferably, where the non-volatile hydrophilic plasticizer is glycerol, it is present at a concentration in water such that the resultant solution ameliorates the stress and distortion of hydrogel articles upon cooling and/or improves the quality of the surface of hydrogel articles upon lathing of the articles. Preferably it is present at

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a concentration of between 5 and 80% by weight. More preferably, it is present at a concentration of between 10 and 50% by weight. Even more preferably the concentration ranges is from 15 to 25% by weight. In the Example presented herein glycerol is provided at a concentration of 15% by weight.

- 5 Those of ordinary skill will appreciate that the non-volatile hydrophilic plasticizer may be contacted with the hydrogel article at the time of machining or prior to the machining process. Whether the hydrogel article is contacted with the non-volatile hydrophilic plasticizer prior to or at the time of machining will depend on such factors as the machining process used, the finish required on the hydrogel
- 10 article and the non-volatile hydrophilic plasticizer selected. Preferably hydrogel articles such as ocular lenticular devices are contacted with the non-volatile hydrophilic plasticizer prior to their machining. In this preferred form, the method of the invention will include the step of: treating the hydrogels in an aqueous solution including at least a non-volatile hydrophilic plasticizer prior to their
- 15 machining in a rigid or semi rigid state.

Where the hydrogel article is to be machined by a lathing process preferably the hydrogel article will be treated in an aqueous solution including at least a non-volatile hydrophilic plasticizer, after which it will be frozen and then lathed in the presence of a non-volatile hydrophilic plasticizer.

- 20 Where the non-volatile hydrophilic plasticizer is brought in contact with the hydrogel article prior to the lathing process, factors such as the finish required, the non-volatile hydrophilic plasticizer used and its concentration will dictate the time that the hydrogel article should be left in contact with the non-volatile hydrophilic plasticizer. Where the hydrogel article is to be lathed to form an ocular lenticular
- 25 device it is preferentially stored at a suitable temperature in the non-volatile hydrophilic plasticizer for between 1 day and 1 month prior to the lathing process. More preferably, the hydrogel article is stored at a suitable temperature in the non-volatile hydrophilic plasticizer for at least 2 weeks prior to lathing.

- Suitable storage temperatures for use in the method of the invention will generally
- 30 be between 0°C and 40°C. Preferably the storage temperature will be between

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10°C and 30°C, more preferably 20°C and 27°C and desirably it will be room temperature.

The time period over which the hydrogel article is maintained at a temperature to render it sufficiently rigid for mechanical processing will vary depending on the  
5 type of hydrogel used, the type of non-volatile hydrophilic plasticizer that has been contacted with the hydrogel article and the size of the hydrogel article specimen. Preferably, such a time period will be between 30 and 120 minutes, however those of ordinary skill will be able to recognise precise times through practical examination of the hydrogel and the non-volatile hydrophilic plasticizer over the  
10 course of its contact with the low temperature conditions.

The precise temperature required to render the hydrogel article sufficiently rigid for mechanical processing will vary depending on the type of hydrogel used and on the lathing process employed. In one specific form of the invention hydrogel articles of PHEMA are placed in a freezer at approximately -80°C where they are  
15 kept for a period of time suitable for them to become rigid. A jet of dry ice is directed to the hydrogel article during lathing to maintain the rigid state.

In a further embodiment of the invention the method may include another pre-treatment step, which involves pre-treating the hydrogel article in an aqueous solution of the non-volatile hydrophilic plasticizer at elevated temperatures to cure  
20 the hydrogel article. Preferably, the hydrogel article is maintained at the elevated temperature for between about 1 to 24 hours. More preferably, the hydrogel article is maintained at the elevated temperature for between about 2 to 12 hours and more preferably still, the hydrogel article is maintained at the elevated temperature for between about 6 to 10 hours. Usually such a step will be  
25 employed as part of the curing process for the hydrogel.

Preferably the elevated temperatures will be less than those required to damage the hydrogel. More preferably the temperature will be between room temperature and 80°C, most preferably between 50°C and 80°C.

Where the hydrogel article is exposed to a curing step prior to lathing, the non-  
30 volatile hydrophilic plasticizer may be contacted with the hydrogel article prior to

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curing. Where the non-volatile hydrophilic plasticizer is brought in contact with the hydrogel article prior to curing, the non-volatile hydrophilic plasticizer is selected to withstand the curing process without chemical decomposition. A particular non-volatile hydrophilic plasticizer suitable for this step in the method would be  
5 glycerol.

After curing preferably the hydrogel article is contacted with the non-volatile hydrophilic plasticizer for between 1 day and 1 month, after which it is frozen and then machined by lathing.

While one of ordinary skill will appreciate that the present invention may be  
10 incorporated into any hydrogel lathing process, preferably the method is used to provide ocular lenticular devices with improved surface smoothness and improved optical quality.

In a highly preferred form of the present invention the method comprises the following steps:

- 15 a Hydrogel articles are placed in water comprising 5 % to 80 % by weight of a non-volatile hydrophilic plasticizer and stored for at least 2 weeks at room temperature;
- b The articles are placed in a freezer at approximately  $-80^{\circ}\text{C}$  where they are kept for 30 to 120 minutes; and
- 20 c The articles are mounted on a lathe and machined to the desired dimensional parameters while the rigid state of the article is maintained by the direction of a jet of dry ice onto the article.

According to the invention there is also provided improved ocular lenticular devices produced according to the methods of the present invention. Such  
25 ocular lenticular devices will be identified by their superior surface smoothness and improved optical quality compared to ocular lenticular devices that have not been processed according to the method of the invention.

#### BEST MODE(S) FOR CARRYING OUT THE INVENTION

The invention will be described in further details and illustrated by way of the  
30 Figures and Examples embodying the method of the invention. The Figures and

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Examples are set forth for the purpose of illustration and any specific exposition of details contained therein should not be interpreted as a limitation.

According to one exemplified form of the invention there is provided a method for manufacturing an artificial cornea.

- 5 According to this example the artificial cornea is manufactured according to the methods described in Australian Patent 650156, and U.S. Patents 5,300,116 and 5,458,819, all issued to the present applicant. Specifically, these methods describe an artificial cornea, or a keratoprosthesis, as a one-piece core-and-skirt device, comprised of intimately attached central and peripheral portions. The core  
10 is a transparent lenticular part composed essentially of a hydrogel, while the peripheral portion is an annular skirt composed of a like hydrogel but in a porous form. A suitable material for both parts is, for example, a polymer of HEMA, commonly designated as PHEMA.

- To produce the hydrogel article as a blank, the porous skirt was made in a  
15 specially designed mould by polymerising an aqueous solution of 20% by weight HEMA (with a purity of 99% by weight) in the presence of divinyl glycol as a crosslinking agent, and of ammonium persulfate solution and tetramethylethylenediamine as initiators, at room temperature for at least 22 hours.

- 20 The transparent core was made in the central zone of the same mould by polymerising an aqueous solution of 70% by weight HEMA, in the presence of ethylene dimethacrylate as a crosslinking agent, and of the aforementioned initiators, at 50°C for at least 22 hours. The resulting blank was then placed in a solution of 15% by weight glycerol in distilled and deionised water and kept in an  
25 oven at 60°C for 8 hours to cure. The blank was then stored in the aforementioned glycerol solution for at least a further 2 weeks.

The blank was mounted onto a chuck and stored in a freezer at -80°C for 45 minutes. The blank was inserted in the lathe and lathed. During machining, low temperature was maintained by using a source of dry ice jet directed to the blank.

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The final hydrogel article was then subjected to operations known in the art, including Soxhlet extraction, sterilization, and packing.

FIG. 2 shows the quality of the resulting surface. FIG. 1 shows the lathed surface of a blank that was not subjected to treatment with glycerol.

- 5 While an advantageous and preferred embodiment of the invention has been selected as an illustration of the invention, it should be understood by those skilled in the art that changes and adaptations regarding the type of hydrogel, and the non-volatile hydrophilic plasticizer can be made without departing from the scope of the invention as defined in the appended claims. It is to be understood that the
- 10 invention includes all such variation and modifications. The invention also includes all of the steps, features, compositions and compounds referred to or indicated in the specification, individually or collectively, and any and all combinations or any two or more of the steps or features.

- The present invention is not to be limited in scope by the specific embodiments
- 15 described herein, which are intended for the purpose of exemplification only. Functionally equivalent products, compositions and methods are clearly within the scope of the invention as described herein.

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS

1. A method of improving the surface quality of hydrogel articles comprising the step of: processing the article in a workable state in the presence of a non-volatile hydrophilic plasticizer.
- 5 2. A method according to claim 1 wherein the hydrogel article is processed by mechanical means that are capable of modifying or improving a hydrogel's shape, profile or surface.
3. A method according to claim 1, wherein the hydrogel article is processed by mechanical lathing.
- 10 4. A method according to claim 1, wherein the hydrogel article is processed in a rigid or sufficiently rigid state to permit lathing, grinding polishing and/or cutting.
5. A method according to claim 1, wherein the hydrogel article is processed in a frozen state.
- 15 6. A method according to any of the preceding claims wherein the non-volatile hydrophilic plasticizer is a water-soluble cryoprotective agent.
7. A method according to any of the preceding claims wherein the non-volatile hydrophilic plasticizer may be selected from glycerol, glycols, poly(ethylene glycols), polyols, water-soluble synthetic polymers (e.g. polyvinylpyrrolidone),  
20 gelatin, albumin, natural gums, monosaccharides and polysaccharides.
8. A method according to any of the preceding claims wherein the non-volatile hydrophilic plasticizer is glycerol.
9. A method according to any of the preceding claims wherein the hydrogel is processed in the presence of more than one non-volatile hydrophilic  
25 plasticizer.
10. A method according to claim 9, wherein one of the non-volatile hydrophilic plasticizers is glycerol.



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11. A method according to claims 9 or 10 where the plasticizers are miscible with each other.
12. A method according to any of the preceding claims wherein the non-volatile hydrophilic plasticizer is present at a concentration of between about 5 and 80% by weight.
13. A method according to any of the preceding claims wherein the non-volatile hydrophilic plasticizer is present at a concentration of between about 10 and 50% by weight.
14. A method according to any of the preceding claims wherein the non-volatile hydrophilic plasticizer is present at a concentration of between about 15 to 25% by weight.
15. A method according to any of the preceding claims wherein the non-volatile hydrophilic plasticizer is present at a concentration of about 15% by weight.
16. A method according to any of the preceding claims comprising the additional step of treating the hydrogels in an aqueous solution including at least a non-volatile hydrophilic plasticizer prior to their machining.
17. A method according to claim 16, wherein the hydrogel is stored in the non-volatile hydrophilic plasticizer for between 1 day and 1 month prior to mechanical processing.
18. A method according to claim 16, wherein the hydrogel is stored in the non-volatile hydrophilic plasticizer for at least 2 weeks prior to mechanical processing.
19. A method according to any of the preceding claims wherein the hydrogel is maintained at a low temperature prior to mechanical processing.
20. A method according to any of the preceding claims wherein the hydrogel material is maintained at about  $-80^{\circ}\text{C}$  prior to mechanical processing.

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21. A method according to any of the preceding claims wherein the hydrogel material is maintained at a low temperature for between about 30 to 120 minutes prior to mechanical processing.
22. A method according to any of the preceding claims comprising the additional  
5 step of subjecting the hydrogel to a cooling source during mechanical processing.
23. A method according to claim 22 wherein the cooling source is a dry ice jet directed to the hydrogel.
24. A method according to any of the preceding claims wherein comprising the  
10 additional step of: curing the hydrogel prior to mechanical processing.
25. A method according to claim 24 where non-volatile hydrophilic plasticizer is contacted with the hydrogel prior to curing.
26. A method according to claims 24 or 25 wherein the non-volatile hydrophilic plasticizer is selected to withstand the curing process without chemical  
15 decomposition.
27. A method according to any of the preceding claims where the hydrogel is selected from
- a. Hydrogels derived from 2-hydroxyethyl methacrylate (henceforth designated as HEMA), crosslinked with any of the agents known in the  
20 art;
  - b. Hydrogels derived from other hydroxylated methacrylates and acrylates, such as 2-hydroxyethyl acrylate, 2-hydroxypropyl methacrylate and acrylate, glycerol methacrylates and acrylates, and many other well known in the art, as such or as mixtures thereof,  
25 crosslinked with any of the agents known in the art;
  - c. Copolymers of HEMA with hydrophobic aliphatic methacrylates or acrylates, such as methyl methacrylate, or other members of the homologue series, crosslinked with any of the agents known in the art;

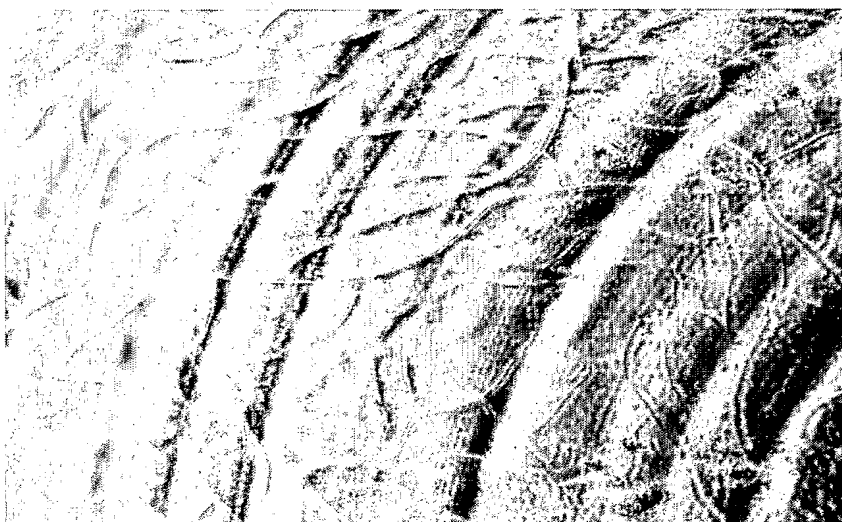
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- d. Copolymers of HEMA with 2-alkoxyalkyl methacrylates or acrylates, such as 2-ethoxyethyl methacrylate, crosslinked with any of the agents known in the art;
- 5 e. Polymers and copolymers derived from acrylamide and its derivatives, and various combinations with hydroxylated methacrylates and acrylates, or with N-vinylpyrrolidone and derivatives, crosslinked with any of the agents known in the art;
- 10 f. Polymers and copolymers derived from N-vinylpyrrolidone and its derivatives, and various combinations with hydroxylated methacrylates and acrylates, or with acrylamide and derivatives, crosslinked with any of the agents known in the art;
- g. Copolymers of HEMA, or of any of the aforementioned monomers, with methacrylates or acrylates of poly(ethylene glycols), crosslinked with any of the agents known in the art;
- 15 h. Silicone acrylate hydrogels, crosslinked with any of the agents known in the art.
28. A method for improving the mechanical processability of a hydrogel comprising the steps of:
- 20 - curing the hydrogel in a hydrated state;
- placing the cured hydrogel in water containing 5 % to 80 % by weight of a non-volatile hydrophilic plasticizer;
- storing the hydrogel for at least 2 weeks at room temperature;
- cooling the hydrogel to about -80 °C;
- 25 - maintaining the hydrogel at that temperature for between about 30 to 120 minutes; and
- mounting the hydrogel on a lathe and machining it to the desired dimensional parameters while the low temperature is maintained.
29. A method according to any of the preceding claims wherein the hydrogel is provided in the form of an ocular lenticular device.

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30. A method according to claim 29 wherein the ocular lenticular device is a contact lens, intraocular lens or artificial cornea.
31. An ocular lenticular device prepared by the method according to any of the preceding claims.
- 5 32. An artificial cornea prepared by the method according to any of claims 1 to 31.
33. A method for improving the mechanical processability of a hydrogel substantially as hereinbefore described with reference to the example.
34. An artificial cornea substantially as hereinbefore described with reference to  
10 the example.
35. An artificial cornea substantially as hereinbefore described with reference to the figures.

1/1



**Fig. 1.**



**Fig. 2.**

# INTERNATIONAL SEARCH REPORT

International application No.  
**PCT/AU03/00134**

<b>A. CLASSIFICATION OF SUBJECT MATTER</b>												
Int. Cl. <sup>7</sup> : C08J 7/00, 5/00; A61L 27/54; B29D 11/00; A61F 2/14; G02C 7/04												
According to International Patent Classification (IPC) or to both national classification and IPC												
<b>B. FIELDS SEARCHED</b>												
Minimum documentation searched (classification system followed by classification symbols)												
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched												
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) DWPI, JAPIO:B29D 11/00, hydrogel												
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>												
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.										
X	EP 473 553 A (CIBA-GEIGY AG) 4 March 1992 Page 2 line 52-page 3 line1	1,7-15,27,29-31										
X	WO 98/07554 A (NOVARTIS AG) 26 February 1998 Page 3 and examples	1,7,8,27,29-31										
X	WO 94/07687 A (KABI PHARMACIA AB) 14 April 1994 Page 5 and examples	1,7,8,29-32										
<input type="checkbox"/> Further documents are listed in the continuation of Box C <input checked="" type="checkbox"/> See patent family annex												
<p>* Special categories of cited documents:</p> <table border="0"> <tr> <td>"A" document defining the general state of the art which is not considered to be of particular relevance</td> <td>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</td> </tr> <tr> <td>"E" earlier application or patent but published on or after the international filing date</td> <td>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</td> </tr> <tr> <td>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</td> <td>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</td> </tr> <tr> <td>"O" document referring to an oral disclosure, use, exhibition or other means</td> <td>"&amp;" document member of the same patent family</td> </tr> <tr> <td>"P" document published prior to the international filing date but later than the priority date claimed</td> <td></td> </tr> </table>			"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family	"P" document published prior to the international filing date but later than the priority date claimed	
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention											
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone											
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art											
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family											
"P" document published prior to the international filing date but later than the priority date claimed												
Date of the actual completion of the international search 7 April 2003		Date of mailing of the international search report <b>14 APR 2003</b>										
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustalia.gov.au Facsimile No. (02) 6285 3929		Authorized officer  <b>GAYE HOROBIN</b> Telephone No : (02) 6283 2069										

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

**PCT/AU03/00134**

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member	
EP	473 553	AU	83526/91
		JP	4340920
WO	9807554	AU	44548/97
WO	9407687	EP	625941
		CA	2050196
		PT	98809
		IE	913072
		US	5174929
		EP	923441
		SE	9202925
		US	5429838
END OF ANNEX			